Tutorial T-2: Massive MIMO for 5G: Fundamentals and Recent Theory

Presenters: Erik G. Larsson and Emil Björnson (Linköping University, Sweden)

Tutorial Overview

The next generation wireless networks need to accommodate 1000x more data traffic than contemporary networks. Since the spectrum is scarce in the bands suitable for coverage, the main improvements need to come from spatial reuse of spectrum; many concurrent transmissions per area unit. This is made possible by the massive MIMO technology, where the access points are equipped with hundreds of antennas. These antennas are phase-synchronized and can thus radiate the data signals to multiple users such that each signal only adds up coherently at its intended user.

Over the last the couple of years, massive MIMO has gone from being a theoretical concept to becoming one of the most promising ingredients of the emerging 5G technology. This is because it provides a way to improve the area spectral efficiency (bit/s/Hz/area) under realistic conditions, by upgrading existing base stations. In other words, massive MIMO is a commercially attractive solution since 100x higher efficiency is possible without installing 100x more base stations.

This tutorial introduces the basic communication theory and motivation behind massive MIMO, as well as recent theoretical results on power control, energy efficiency, and impact of hardware impairments. The following is a rough outline:

PART 1 (First 1.5 hours)

Motivation and Case Studies
- Expectations on 5G networks
- Basic idea of Massive MIMO and motivating examples

Models and Fundamental Assumptions
- Channel coherence time and bandwidth
- Time division duplex (TDD) operation, reciprocity
- Frame structure, pilots and payload

Favorable Propagation
- The concept of “favorable propagation”
- Capacity bounds and case studies

Single-Cell Operation
- Uplink and downlink capacity with linear algorithms
- Limiting factors of Massive MIMO

Multi-Cell Systems
- Pilot reuse and pilot contamination
- Single-cell vs. multi-cell: Similarities and differences

PART 2 (Second 1.5 hours)

Uniform User Performance
- Power-control policies
- Pilot Reuse Patterns

- How many users can be served?
Impact of Hardware Impairments
- Modeling of different types of impairments
- Capacity expressions and asymptotic results
- Hardware Scaling Laws
Energy Efficiency
- Power consumption and scaling laws
- Radiated vs. total power
- Massive MIMO vs. small cells
Myths around Massive MIMO
- What are the common misconceptions?

This tutorial is non-overlapping with the massive MIMO tutorial T-7 on Monday afternoon, which deals with practical implementation issues. You can attend any or preferably both of these tutorials.

Presenter Biographies

Erik G. Larsson is Professor and Head of the Division for Communication Systems in the Department of Electrical Engineering (ISY) at Linköping University (LiU) in Linköping, Sweden. He joined LiU in September 2007. He has previously held positions at the KTH Royal Institute of Technology in Stockholm, University of Florida, George Washington University (USA), and Ericsson Research (Stockholm). He received his Ph.D. from Uppsala University in 2002. His main professional interests are within the areas of wireless communications and signal processing. He has published some 100 journal papers on these topics, he is co-author of the textbook Space-Time Block Coding for Wireless Communications (Cambridge Univ. Press, 2003) and he holds 10 issued and many pending patents on wireless technology.
He has served as Associate Editor for several major journals, including the IEEE Transactions on Communications (2010-2014) and the IEEE Transactions on Signal Processing (2006-2010). He serves as chair of the IEEE Signal Processing Society SPCOM technical committee in 2015. He is also chair of the steering committee for the IEEE Wireless Communications Letters (2014-2015). He is active in conference organization, recently as General Chair of the Asilomar Conference on Signals, Systems and Computers 2015. He received the IEEE Signal Processing Magazine Best Column Award 2012.

Emil Björnson is Assistant Professor at the Division of Communication Systems at Linköping University, Sweden. He received the M.S. degree in Engineering Mathematics from Lund University, Sweden, in 2007. He received the Ph.D. degree in Telecommunications from KTH Royal Institute of Technology, Stockholm, Sweden, in 2011. From 2012 to July 2014, he was a joint postdoc at the Alcatel-Lucent Chair on Flexible Radio, Supélec, Paris, France, and KTH Royal Institute of Technology. His research interests include multi-antenna cellular communications, massive MIMO techniques, radio resource allocation, green energy efficient systems, and network topology design. He is the first author of the textbook “Optimal Resource Allocation in Coordinated Multi-Cell Systems” (Foundations and Trends in Communications and Information Theory, 2013). He is dedicated to reproducible research and has published a large amount of simulation code. Dr. Björnson has received 4 best paper awards for novel research on optimization and design of multi-cell multi-antenna communications: IEEE WCNC 2014, IEEE SAM 2014, IEEE CAMSAP 2011, and WCSP 2009.